



General

Guideline Title

2011 ACCF/AHA guideline for coronary artery bypass graft surgery: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines.

Bibliographic Source(s)

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[1264 references] [PubMed](#)

Guideline Status

This is the current release of the guideline.

This guideline updates a previous version: Eagle KA, Guyton RA, Davidoff R, Edwards FH, Ewy GA, Gardner TJ, Hart JC, Herrmann HC, Hillis LD, Hutter AM Jr, Lytle BW, Marlow RA, Nugent WC, Orszulak TA. ACC/AHA 2004 guideline update for coronary artery bypass graft surgery: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. Bethesda (MD): American College of Cardiology; 2004. 99 p.

Recommendations

Major Recommendations

The American College of Cardiology/American Heart Association (ACC/AHA) Classification of the recommendations for patient evaluation and treatment (Classes I-III) and the levels of evidence (A-C) are defined at the end of the "Major Recommendations" field.

Procedural Considerations

Intraoperative Considerations

Anesthetic Considerations

Class I

1. Anesthetic management directed toward early postoperative extubation and accelerated recovery of low- to medium-risk patients undergoing uncomplicated coronary artery bypass grafting (CABG) is recommended (Hawkes, Dhileepan, & Foxcroft, 2003; Myles et al., 2003; van Mastrigt et al., 2006). (Level of Evidence: B)
2. Multidisciplinary efforts are indicated to ensure an optimal level of analgesia and patient comfort throughout the perioperative period (Bainbridge, Martin, & Cheng, 2006; Brennan, Carr, & Cousins, 2007; Lahtinen, Kokki, & Hynynen, 2006; Serfontein, 2010; Taillefer et al., 2006). (Level of Evidence: B)
3. Efforts are recommended to improve interdisciplinary communication and patient safety in the perioperative environment (e.g., formalized checklist-

- guided multidisciplinary communication) (Martinez et al., 2010; Wadhera et al., 2010; Neily et al., 2010; Haynes et al., 2009). (Level of Evidence: B)
4. A fellowship-trained cardiac anesthesiologist (or experienced board-certified practitioner) credentialed in the use of perioperative transesophageal echocardiography (TEE) is recommended to provide or supervise anesthetic care of patients who are considered to be at high risk (Cahalan et al., 2002; Mathew et al., 2006; Thys, 2009). (Level of Evidence: C)

Class IIa

1. Volatile anesthetic-based regimens can be useful in facilitating early extubation and reducing patient recall (Myles et al., 2003; Dowd et al., 1998; Groesdonk, et al., 2010; Cheng et al., "Early," 1996). (Level of Evidence: A)

Class IIb

1. The effectiveness of high thoracic epidural anesthesia/analgesia for routine analgesic use is uncertain (Horlocker et al., 2010; Murphy et al., 2003; Nygard et al., 2005; Tenenbein et al., 2008). (Level of Evidence: B)

Class III: HARM

1. Cyclooxygenase-2 inhibitors are not recommended for pain relief in the postoperative period after CABG (Nussmeier et al., 2005; Ott et al., 2003). (Level of Evidence: B)
2. Routine use of early extubation strategies in facilities with limited backup for airway emergencies or advanced respiratory support is potentially harmful. (Level of Evidence: C)

Bypass Graft Conduit

Class I

1. If possible, the left internal mammary artery (LIMA) should be used to bypass the left anterior descending (LAD) artery when bypass of the LAD artery is indicated (Boylan et al., 1994; Cameron et al., 1996; Loop et al., 1986; Sabik et al., 2005). (Level of Evidence: B)

Class IIa

1. The right internal mammary artery (IMA) is probably indicated to bypass the LAD artery when the LIMA is unavailable or unsuitable as a bypass conduit. (Level of Evidence: C)
2. When anatomically and clinically suitable, use of a second IMA to graft the left circumflex or right coronary artery (when critically stenosed and perfusing left ventricle [LV] myocardium) is reasonable to improve the likelihood of survival and to decrease reintervention (Lytle et al., 1999; Lytle et al., 2004; Sabik et al., 2006; Sabik et al., 2008; Stevens et al., 2004). (Level of Evidence: B)

Class IIb

1. Complete arterial revascularization may be reasonable in patients less than or equal to 60 years of age with few or no comorbidities. (Level of Evidence: C)
2. Arterial grafting of the right coronary artery may be reasonable when a critical ($\geq 90\%$) stenosis is present (Sabik et al., 2005; Sabik et al., 2008; Sabik et al., 2003). (Level of Evidence: B)
3. Use of a radial artery graft may be reasonable when grafting left-sided coronary arteries with severe stenoses ($> 70\%$) and right-sided arteries with critical stenoses ($\geq 90\%$) that perfuse LV myocardium (Acar et al., 1998; Maniar et al., 2002; Moran et al., 2001; Possati et al., 1998; Royse et al., 2000; Desai, et al., 2004). (Level of Evidence: B)

Class III: HARM

1. An arterial graft should not be used to bypass the right coronary artery with less than a critical stenosis ($< 90\%$) (Sabik et al., 2005). (Level of Evidence: C)

Intraoperative TEE

Class I

1. Intraoperative TEE should be performed for evaluation of acute, persistent, and life-threatening hemodynamic disturbances that have not responded to treatment (Eltzschig et al., 2008; Savage et al., 1997). (Level of Evidence: B)
2. Intraoperative TEE should be performed in patients undergoing concomitant valvular surgery (Eltzschig et al., 2008; American Society of Anesthesiologists and Society of Cardiovascular Anesthesiologists, 2010). (Level of Evidence: B)

Class IIa

1. Intraoperative TEE is reasonable for monitoring of hemodynamic status, ventricular function, regional wall motion, and valvular function in patients undergoing CABG (Savage, et al., 1997; Bergquist, Bellows, & Leung, 1996; Moises et al., 1998; Qaddoura et al., 2004; Swaminathan et al., 2007; Wang et al., 2004; Zimarino et al., 2004). (Level of Evidence: B)

Preconditioning/Management of Myocardial Ischemia

Class I

1. Management targeted at optimizing the determinants of coronary arterial perfusion (e.g., heart rate, diastolic or mean arterial pressure, and right ventricular or LV end-diastolic pressure) is recommended to reduce the risk of perioperative myocardial ischemia and infarction (Slogoff & Keats, 1985; Dyub et al., 2008; Heusch, 2008; Gibbons et al., 2002; Lavana et al., 2010). (Level of Evidence: B)

Class IIa

1. Volatile-based anesthesia can be useful in reducing the risk of perioperative myocardial ischemia and infarction (Landoni et al., "Desflurane," 2007; Lucchinetti et al., 2007; Yao & Li, 2009; Yu & Beattie, 2006). (Level of Evidence: A)

Class IIb

1. The effectiveness of prophylactic pharmacological therapies or controlled reperfusion strategies aimed at inducing preconditioning or attenuating the adverse consequences of myocardial reperfusion injury or surgically induced systemic inflammation is uncertain (Rabi et al., 2010; Buckberg, 2010; MEND-CABG II Investigators et al., 2008; Mangano, 1997; Mangano et al., 2006; Shernan et al., 2004; Smith et al., 2011; Testa et al., 2008). (Level of Evidence: A)
2. Mechanical preconditioning might be considered to reduce the risk of perioperative myocardial ischemia and infarction in patients undergoing off-pump CABG (Laurikka et al., 2002; Penttila et al., 2003; Walsh et al., 2008). (Level of Evidence: B)
3. Remote ischemic preconditioning strategies using peripheral-extremity occlusion/reperfusion might be considered to attenuate the adverse consequences of myocardial reperfusion injury (Hausenloy et al., 2007; Rahman et al., 2010; Venugopal et al., 2009). (Level of Evidence: B)
4. The effectiveness of postconditioning strategies to attenuate the adverse consequences of myocardial reperfusion injury is uncertain (Luo et al., 2008; Ozive et al., 2010). (Level of Evidence: C)

Clinical Subsets

CABG in Patients with Acute Myocardial Infarction (MI)

Class I

1. Emergency CABG is recommended in patients with acute MI in whom 1) primary percutaneous coronary intervention (PCI) has failed or cannot be performed, 2) coronary anatomy is suitable for CABG, and 3) persistent ischemia of a significant area of myocardium at rest and/or hemodynamic instability refractory to nonsurgical therapy is present (Alexiou et al., 2008; Chiu et al., 2009; DeWood et al., 1983; Donatelli et al., 1997; Filizcan et al., 2011). (Level of Evidence: B)
2. Emergency CABG is recommended in patients undergoing surgical repair of a postinfarction mechanical complication of MI, such as ventricular septal rupture, mitral valve insufficiency because of papillary muscle infarction and/or rupture, or free wall rupture (Chevalier et al., 2004; Lemery et al., 1992; Russo et al., 2008; Shamshad et al., 2010; Tavakoli et al., 2002). (Level of Evidence: B)
3. Emergency CABG is recommended in patients with cardiogenic shock and who are suitable for CABG irrespective of the time interval from MI to onset of shock and time from MI to CABG (Donatelli et al., 1997; Hochman et al., 1999; Mehta et al., 2010; White et al., 2005). (Level of Evidence: B)
4. Emergency CABG is recommended in patients with life-threatening ventricular arrhythmias (believed to be ischemic in origin) in the presence of left main stenosis greater than or equal to 50% and/or 3-vessel coronary artery disease (CAD) (Ngaage et al., 2008). (Level of Evidence: C)

Class IIa

1. The use of CABG is reasonable as a revascularization strategy in patients with multivessel CAD with recurrent angina or MI within the first 48 hours of ST segment elevation myocardial infarction (STEMI) presentation as an alternative to a more delayed strategy (Alexiou, et al., 2008; DeWood et al., 1983; Filizcan et al., 2011; Parikh et al., 2010). (Level of Evidence: B)
2. Early revascularization with PCI or CABG is reasonable for selected patients greater than 75 years of age with ST-segment elevation or left bundle branch block who are suitable for revascularization irrespective of the time interval from MI to onset of shock (Lim et al., 2009; Amin et al., 2009; Migliorini et al., 2006; Hochman, et al., 2000; Dzavik et al., 2003). (Level of Evidence: B)

Class III: HARM

1. Emergency CABG should not be performed in patients with persistent angina and a small area of viable myocardium who are stable hemodynamically. (Level of Evidence: C)
2. Emergency CABG should not be performed in patients with no-reflow (successful epicardial reperfusion with unsuccessful microvascular reperfusion). (Level of Evidence: C)

Life-Threatening Ventricular Arrhythmias

Class I

1. CABG is recommended in patients with resuscitated sudden cardiac death or sustained ventricular tachycardia thought to be caused by significant CAD ($\geq 50\%$ stenosis of left main coronary artery and/or $\geq 70\%$ stenosis of 1, 2, or all 3 epicardial coronary arteries) and resultant myocardial ischemia (Ngaage et al., 2008; Every et al., 1992; Kelly et al., 1990). (Level of Evidence: B)

Class III: HARM

1. CABG should not be performed in patients with ventricular tachycardia with scar and no evidence of ischemia. (Level of Evidence: C)

Emergency CABG After Failed PCI

Class I

1. Emergency CABG is recommended after failed PCI in the presence of ongoing ischemia or threatened occlusion with substantial myocardium at risk (Barakate et al., 2003; Roy et al., 2009). (Level of Evidence: B)
2. Emergency CABG is recommended after failed PCI for hemodynamic compromise in patients without impairment of the coagulation system and without a previous sternotomy (Barakate et al., 2003; Craver et al., 1992; Stamou et al., 2006). (Level of Evidence: B)

Class IIa

1. Emergency CABG is reasonable after failed PCI for retrieval of a foreign body (most likely a fractured guidewire or stent) in a crucial anatomic location. (Level of Evidence: C)
2. Emergency CABG can be beneficial after failed PCI for hemodynamic compromise in patients with impairment of the coagulation system and without previous sternotomy. (Level of Evidence: C)

Class IIb

1. Emergency CABG might be considered after failed PCI for hemodynamic compromise in patients with previous sternotomy. (Level of Evidence: C)

Class III: HARM

1. Emergency CABG should not be performed after failed PCI in the absence of ischemia or threatened occlusion. (Level of Evidence: C)
2. Emergency CABG should not be performed after failed PCI if revascularization is impossible because of target anatomy or a no-repair state. (Level of Evidence: C)

CABG in Association with Other Cardiac Procedures

Class I

1. CABG is recommended in patients undergoing noncoronary cardiac surgery with greater than or equal to 50% luminal diameter narrowing of the left main coronary artery or greater than or equal to 70% luminal diameter narrowing of other major coronary arteries. (Level of Evidence: C)

Class IIa

1. The use of the LIMA is reasonable to bypass a significantly narrowed LAD artery in patients undergoing noncoronary cardiac surgery (Level of Evidence: C)
2. CABG of moderately diseased coronary arteries ($>50\%$ luminal diameter narrowing) is reasonable in patients undergoing noncoronary cardiac surgery. (Level of Evidence: C)

CAD Revascularization

Heart Team Approach to Revascularization Decisions

Class I

1. A Heart Team approach to revascularization is recommended in patients with unprotected left main or complex CAD (Serruys et al., 2009; Feit et al., 2000; King et al., 1997). (Level of Evidence: C)

Class IIa

1. Calculation of the Society of Thoracic Surgeons (STS) and SYNTAX scores is reasonable in patients with unprotected left main and complex CAD (Morice et al., 2010; Serruys et al., 2009; Chakravarty et al., 2011; Grover et al., 2001; Kim et al., 2010; Shahian et al., 2009; Shahian et al., 2010; Welke et al., 2007). (Level of Evidence: B)

Revascularization to Improve Survival: Left Main CAD Revascularization

Class I

1. CABG to improve survival is recommended for patients with significant ($\geq 50\%$ diameter stenosis) left main coronary artery stenosis (Caracciolo et al., 1995; Chaitman et al., 1981; Dzavik et al., 2001; Takaro et al., 1976; Takaro et al., 1982; Taylor et al., 1989; Yusuf et al., 1994). (Level of Evidence: B)

Class IIa

1. PCI to improve survival is reasonable as an alternative to CABG in selected stable patients with significant ($\geq 50\%$ diameter stenosis) unprotected left main CAD with: 1) anatomic conditions associated with a low risk of PCI procedural complications and a high likelihood of good long-term outcome (e.g., a low SYNTAX score [≤ 22], ostial or trunk left main CAD); and 2) clinical characteristics that predict a significantly increased risk of adverse surgical outcomes (e.g., STS-predicted risk of operative mortality $\geq 5\%$) (Morice et al., 2010; Chakravarty et al., 2011; Kim et al., 2010; Buszman et al., 2008; Capodanno et al., 2011; Hannan et al., 2008; Ellis et al., 1997; Biondi-Zocca et al., 2008; Boudriot et al., 2011; Brener et al., 2008; Chieffo et al., 2006; Chieffo et al., 2010; Lee et al., 2006; Makikallio et al., 2008; Naik et al., 2009; Palmerini et al., 2006; Park et al., 2010; Rodes-Cabau et al., 2008; Sanmartin et al., 2007; Kappetein et al., 2011; Seung et al., 2008; White et al., 2008). (Level of Evidence: B)
2. PCI to improve survival is reasonable in patients with unstable angina/non-ST segment elevation myocardial infarction (UA/NSTEMI) when an unprotected left main coronary artery is the culprit lesion and the patient is not a candidate for CABG (Morice et al., 2010; Brener et al., 2008; Chieffo et al., 2006; Chieffo et al., 2010; Lee et al., 2006; Rodes-Cabau et al., 2008; Sanmartin et al., 2007; Seung et al., 2008; White et al., 2008; Montalescot et al., 2009). (Level of Evidence: B)
3. PCI to improve survival is reasonable in patients with acute STEMI when an unprotected left main coronary artery is the culprit lesion, distal coronary flow is less than Thrombolysis In Myocardial Infarction grade 3, and PCI can be performed more rapidly and safely than CABG (Ellis et al., 1997; Lee et al., 2008; Lee et al., 2010). (Level of Evidence: C)

Class IIb

1. PCI to improve survival may be reasonable as an alternative to CABG in selected stable patients with significant ($\geq 50\%$ diameter stenosis) unprotected left main CAD with: 1) anatomic conditions associated with a low to intermediate risk of PCI procedural complications and an intermediate to high likelihood of good long-term outcome (e.g., low-intermediate SYNTAX score of < 33 , bifurcation left main CAD); and 2) clinical characteristics that predict an increased risk of adverse surgical outcomes (e.g., moderate-severe chronic obstructive pulmonary disease, disability from previous stroke, or previous cardiac surgery; STS-predicted risk of operative mortality $> 2\%$) (Morice et al., 2010; Chakravarty et al., 2011; Kim et al., 2010; Buszman et al., 2008; Capodanno et al., 2011; Hannan et al., 2008; Ellis et al., 1997; Biondi-Zocca et al., 2008; Boudriot et al., 2011; Brener et al., 2008; Chieffo et al., 2006; Chieffo et al., 2010; Lee et al., 2006; Makikallio et al., 2008; Naik et al., 2009; Palmerini et al., 2006; Park et al., 2010; Rodes-Cabau et al., 2008; Sanmartin et al., 2007; Kappetein et al., 2011; Seung et al., 2008; White et al., 2008; Park et al., 2011). (Level of Evidence: B)

Class III: HARM

1. PCI to improve survival should not be performed in stable patients with significant ($\geq 50\%$ diameter stenosis) unprotected left main CAD who have unfavorable anatomy for PCI and who are good candidates for CABG (Morice et al., 2010; Chakravarty et al., 2011; Kim et al., 2010; Caracciolo et al., 1995; Chaitman et al., 1981; Dzavik et al., 2001; Takaro et al., 1976; Takaro et al., 1982; Taylor et al., 1989; Yusuf et al., 1994; Capodanno et al., 2011; Hannan et al., 2008). (Level of Evidence: B)

Non-Left Main CAD Revascularization

Class I

1. CABG to improve survival is beneficial in patients with significant ($\geq 70\%$ diameter) stenoses in 3 major coronary arteries (with or without involvement of the proximal LAD artery) or in the proximal LAD plus 1 other major coronary artery (Dzavik et al., 2001; Yusuf et al., 1994; Jones et al., "Long-term," 1996; Myers et al., 1989; Smith et al., 2006; Varnauskas, 1988). (Level of Evidence: B)
2. CABG or PCI to improve survival is beneficial in survivors of sudden cardiac death with presumed ischemia-mediated ventricular tachycardia caused by significant ($\geq 70\%$ diameter) stenosis in a major coronary artery. (CABG Level of Evidence: B [Every et al., 1992; Borger van der Burg et al., 2003; Kaiser et al., 1975]; PCI Level of Evidence: C [Borger van der Burg et al., 2003])

Class IIa

1. CABG to improve survival is reasonable in patients with significant ($\geq 70\%$ diameter) stenoses in 2 major coronary arteries with severe or extensive myocardial ischemia (e.g., high-risk criteria on stress testing, abnormal intracoronary hemodynamic evaluation, or $> 20\%$ perfusion defect by myocardial perfusion stress imaging) or target vessels supplying a large area of viable myocardium (Di Carli et al., 1998; Hachamovitch et al., 2003; Soraja et al., 2005; Davies et al., 1997). (Level of Evidence: B)
2. CABG to improve survival is reasonable in patients with mild-moderate LV systolic dysfunction (EF 35% to 50%) and significant ($\geq 70\%$ diameter stenosis) multivessel CAD or proximal LAD coronary artery stenosis, when viable myocardium is present in the region of intended revascularization (Yusuf et al., 1994; Alderman et al., 1983; O'Connor et al., 2002; Phillips, O'Connor, & Rogers, 2007; Tarakji et al., 2006; Tsuyuki et al., 2006). (Level of Evidence: B)
3. CABG with a LIMA graft to improve survival is reasonable in patients with significant ($\geq 70\%$ diameter) stenosis in the proximal LAD artery and evidence of extensive ischemia (Cameron et al., 1996; Loop et al., 1986; Yusuf et al., 1994; Smith et al., 2006). (Level of Evidence: B)

- It is reasonable to choose CABG over PCI to improve survival in patients with complex 3-vessel CAD (e.g., SYNTAX score >22), with or without involvement of the proximal LAD artery, who are good candidates for CABG (Hannan et al., 2008; Kappetein et al., 2011; Smith et al., 2006; Brener et al., 2004; Hannan et al., 2005). (Level of Evidence: B)
- CABG is probably recommended in preference to PCI to improve survival in patients with multivessel CAD and diabetes mellitus, particularly if a LIMA graft can be anastomosed to the LAD artery (Sorajja et al., 2005; "Influence of diabetes," 1997; BARI Investigators, 2007; Banning et al., 2010; Hoffman et al., 2003; Hueb et al., 2007; Malenka et al., 2005; Niles et al., 2001; Weintraub et al., 1998). (Level of Evidence: B)

Class IIb

- The usefulness of CABG to improve survival is uncertain in patients with significant ($\geq 70\%$) stenoses in 2 major coronary arteries not involving the proximal LAD artery and without extensive ischemia (Smith et al., 2006). (Level of Evidence: C)
- The usefulness of PCI to improve survival is uncertain in patients with 2- or 3-vessel CAD (with or without involvement of the proximal LAD artery) or 1-vessel proximal LAD disease (Dzavik et al., 2001; Jones et al., "Long-term," 1996; Smith et al., 2006; Boden et al., 2007). (Level of Evidence: B)
- CABG might be considered with the primary or sole intent of improving survival in patients with silent ischemic heart disease (SIHD) with severe LV systolic dysfunction (EF <35%) whether or not viable myocardium is present (Yusuf et al., 1994; Alderman et al., 1983; O'Connor et al., 2002; Phillips, O'Connor, & Rogers, 2007; Tarakji et al., 2006; Tsuyuki et al., 2006; Bonow et al., 2011; Velazquez et al., 2011). (Level of Evidence: B)
- The usefulness of CABG or PCI to improve survival is uncertain in patients with previous CABG and extensive anterior wall ischemia on noninvasive testing (Brener et al., 2006; Gurinkel et al., 2007; Lytle et al., 1993; Morrison et al., 2001; Pfautsch et al., 1999; Sergeant, "First," et al., 1998; Stephan et al., 1996; Subramanian et al., 2009; Weintraub et al., 1997). (Level of Evidence: B)

Class III: HARM

- CABG or PCI should not be performed with the primary or sole intent to improve survival in patients with SIHD with 1 or more coronary stenoses that are not anatomically or functionally significant (e.g., <70% diameter non-left main coronary artery stenosis, fractional flow reserve >0.80, no or only mild ischemia on noninvasive testing), involve only the left circumflex or right coronary artery, or subtend only a small area of viable myocardium (Yusuf et al., 1994; Jones et al., "Long-term," 1996; Di Carli et al., 1998; Hachamovitch et al., 2003; Shaw et al., 2008; Cashin et al., 1984; Pijls NH et al., 1996; Tonino et al., 2009; Sawada et al., 2003). (Level of Evidence: B)

Revascularization to Improve Symptoms

Class I

- CABG or PCI to improve symptoms is beneficial in patients with 1 or more significant ($\geq 70\%$ diameter) coronary artery stenoses amenable to revascularization and unacceptable angina despite guideline-directed medical therapy (GDMT) (Boden et al., 2007; TIME Investigators, 2001; Benzer, Hofer, & Oldridge, 2003; Bonaros et al., 2005; Bucher et al., 2000; Favarato et al., 2007; Hueb et al., 2010; Pocock et al., 1996; Pocock et al., 2000; Weintraub et al., 2008; Wijeyasundera et al., 2010). (Level of Evidence: A)

Class IIa

- CABG or PCI to improve symptoms is reasonable in patients with 1 or more significant ($\geq 70\%$ diameter) coronary artery stenoses and unacceptable angina for whom GDMT cannot be implemented because of medication contraindications, adverse effects, or patient preferences. (Level of Evidence: C)
- PCI to improve symptoms is reasonable in patients with previous CABG, 1 or more significant ($\geq 70\%$ diameter) coronary artery stenoses associated with ischemia, and unacceptable angina despite GDMT (Gurinkel et al., 2007; Pfautsch et al., 1999; Subramanian et al., 2009). (Level of Evidence: C)
- It is reasonable to choose CABG over PCI to improve symptoms in patients with complex 3-vessel CAD (e.g., SYNTAX score >22), with or without involvement of the proximal LAD artery, who are good candidates for CABG (Hannan et al., 2008; Kappetein et al., 2011; Smith et al., 2006; Brener et al., 2004; Hannan et al., 2005). (Level of Evidence: B)

Class IIb

- CABG to improve symptoms might be reasonable for patients with previous CABG, 1 or more significant ($\geq 70\%$ diameter) coronary artery stenoses not amenable to PCI, and unacceptable angina despite GDMT (Weintraub et al., 1997). (Level of Evidence: C)
- Transmyocardial laser revascularization (TMR) performed as an adjunct to CABG to improve symptoms may be reasonable in patients with viable ischemic myocardium that is perfused by arteries that are not amenable to grafting (Schoeld et al., 1999; Aaberge et al., 2000; Burkhoff et al., 1999; Allen et al., 2000; Stamou et al., 2002). (Level of Evidence: B)

Class III: HARM

- CABG or PCI to improve symptoms should not be performed in patients who do not meet anatomic ($\geq 50\%$ left main or $\geq 70\%$ non-left main stenosis) or physiological (e.g., abnormal fractional flow reserve) criteria for revascularization. (Level of Evidence: C)

Dual Anti-Platelet Therapy (DAPT) Compliance and Stent Thrombosis

Class III: HARM

1. PCI with coronary stenting (bare-metal stent [BMS] or drug-eluting stent [DES]) should not be performed if the patient is not likely to be able to tolerate and comply with DAPT for the appropriate duration of treatment based on the type of stent implanted (Grines et al., 2007; Leon et al., 1998; Mauri et al., 2007; McFadden et al., 2004). (Level of Evidence: B)

Hybrid Coronary Revascularization

Class IIa

1. Hybrid coronary revascularization (defined as the planned combination of LIMA-to-LAD artery grafting and PCI of ≥ 1 non-LAD coronary arteries) is reasonable in patients with 1 or more of the following (Bonatti et al., 2008; Gilard et al., 2007; Holzhey et al., 2008; Kon et al., 2008; Reicher et al., 2008; Vassiliades et al., 2006; Zhao et al., 2009; Angelini et al., 1996; Simoons, 1996) (Level of Evidence: B):
 - a. Limitations to traditional CABG, such as heavily calcified proximal aorta or poor target vessels for CABG (but amenable to PCI);
 - b. Lack of suitable graft conduits;
 - c. Unfavorable LAD artery for PCI (i.e., excessive vessel tortuosity or chronic total occlusion).

Class IIb

1. Hybrid coronary revascularization (defined as the planned combination of LIMA-to-LAD artery grafting and PCI of ≥ 1 non-LAD coronary arteries) may be reasonable as an alternative to multivessel PCI or CABG in an attempt to improve the overall risk–benefit ratio of the procedures. (Level of Evidence: C)

Perioperative Management

Preoperative Antiplatelet Therapy

Class I

1. Aspirin (100 mg to 325 mg daily) should be administered to CABG patients preoperatively (Bybee et al., 2005; Dacey et al., 2000; Mangano, 2002). (Level of Evidence: B)
2. In patients referred for elective CABG, clopidogrel and ticagrelor should be discontinued for at least 5 days before surgery (Berger et al., 2008; Held et al., 2011; Hongo et al., 2002) (Level of Evidence: B) and prasugrel for at least 7 days (Level of Evidence: C) to limit blood transfusions.
3. In patients referred for urgent CABG, clopidogrel and ticagrelor should be discontinued for at least 24 hours to reduce major bleeding complications (Held et al., 2011; Firanscu et al., 2009; Herman et al., 2010; Mehta et al., 2009). (Level of Evidence: B)
4. In patients referred for CABG, short-acting intravenous glycoprotein IIb/IIIa inhibitors (eptifibatide or tirofiban) should be discontinued for at least 2 to 4 hours before surgery (Bizzarri et al., 2001; Dyke et al., 2000) and abciximab for at least 12 hours beforehand (Lincoff et al., 2000) to limit blood loss and transfusions. (Level of Evidence: B)

Class IIb

1. In patients referred for urgent CABG, it may be reasonable to perform surgery less than 5 days after clopidogrel or ticagrelor has been discontinued and less than 7 days after prasugrel has been discontinued. (Level of Evidence: C)

Postoperative Antiplatelet Therapy

Class I

1. If aspirin (100 mg to 325 mg daily) was not initiated preoperatively, it should be initiated within 6 hours postoperatively and then continued indefinitely to reduce the occurrence of saphenous vein graft (SVG) closure and adverse cardiovascular events (Mangano, 2002; Sethi et al., 1990; Antithrombotic Trialists' Collaboration, 2002). (Level of Evidence: A)

Class IIa

1. For patients undergoing CABG, clopidogrel 75 mg daily is a reasonable alternative in patients who are intolerant of or allergic to aspirin. (Level of Evidence: C)

Management of Hyperlipidemia

Class I

1. All patients undergoing CABG should receive statin therapy, unless contraindicated (Campeau et al., 1997; "Third Report," 2002; Cholesterol Treatment Trialists' (CTT) Collaboration et al., 2010; Pedersen et al., 2005; LaRosa et al., 2005; Heart Protection Study Collaborative Group, 2002; Dotani et al., 2000; Mannacio et al., 2008; Liakopoulos et al., 2008; Knatterud et al., 2000; Christenson, 1999; Pascual et al., 2006; Pan et al., 2004). (Level of Evidence: A)
2. In patients undergoing CABG, an adequate dose of statin should be used to reduce LDL cholesterol to less than 100 mg/dL and to achieve at least a 30% lowering of LDL cholesterol (Campeau et al., 1997; "Third Report," 2002; CTT Collaboration et al., 2010; Pedersen et al., 2005; LaRosa et al.,

2005; Heart Protection Study Collaborative Group, 2002). (Level of Evidence: C)

Class IIa

1. In patients undergoing CABG, it is reasonable to treat with statin therapy to lower the LDL cholesterol to less than 70 mg/dL in very high-risk* patients (CTT Collaboration et al., 2010; Pedersen et al., 2005; LaRosa et al., 2005; Cannon et al., 2004; Cannon et al., 2006; Grundy et al., 2004). (Level of Evidence: C)
2. For patients undergoing urgent or emergency CABG who are not taking a statin, it is reasonable to initiate high-dose statin therapy immediately ("Food and Drug Administration [FDA] safety alert," 2011). (Level of Evidence: C)

*Presence of established cardiovascular disease plus 1) multiple major risk factors (especially diabetes), 2) severe and poorly controlled risk factors (especially continued cigarette smoking), 3) multiple risk factors of the metabolic syndrome (especially high triglycerides ≥ 200 mg/dL plus non-high-density lipoprotein cholesterol ≥ 130 mg/dL with low high-density lipoprotein cholesterol [<40 mg/dL]), and 4) acute coronary syndromes.

Class III: HARM

1. Discontinuation of statin or other dyslipidemic therapy is not recommended before or after CABG in patients without adverse reactions to therapy (Collard et al., 2006; Kulik et al., 2008; Thielmann et al., 2007). (Level of Evidence: B)

Hormonal Manipulation

Class I

1. Use of continuous intravenous insulin to achieve and maintain an early postoperative blood glucose concentration less than or equal to 180 mg/dL while avoiding hypoglycemia is indicated to reduce the incidence of adverse events, including deep sternal wound infection, after CABG (Furnary et al., 2003; Ingels et al., 2006; van den Berghe et al., 2001). (Level of Evidence: B)

Class IIb

1. The use of continuous intravenous insulin designed to achieve a target intraoperative blood glucose concentration less than 140 mg/dL has uncertain effectiveness (Butterworth et al., 2005; Duncan et al., 2010; Gandhi et al., 2007). (Level of Evidence: B)

Class III: HARM

1. Postmenopausal hormonal therapy (estrogen/progesterone) should not be administered to women undergoing CABG (Hulley et al., 1998; Rossouw et al., 2002; Ouyang et al., 2006). (Level of Evidence: B)

Perioperative Beta Blockers

Class I

1. Beta blockers should be administered for at least 24 hours before CABG to all patients without contraindications to reduce the incidence or clinical sequelae of postoperative atrial fibrillation (AF) (Crystal et al., 2004; Connolly et al., 2003; Andrews et al., 1991; Mariscalco et al., 2008; Fuster et al., 2011; Al-Khatib et al., 2009; Silverman, Wright, & Levitsky, 1982; Ali, Sanalla, & Clark, 1997). (Level of Evidence: B)
2. Beta blockers should be reinstated as soon as possible after CABG in all patients without contraindications to reduce the incidence or clinical sequelae of AF (Crystal et al., 2004; Connolly et al., 2003; Andrews et al., 1991; Mariscalco et al., 2008; Fuster et al., 2011; Al-Khatib et al., 2009; Silverman, Wright, & Levitsky, 1982; Ali, Sanalla, & Clark, 1997). (Level of Evidence: B)
3. Beta blockers should be prescribed to all CABG patients without contraindications at the time of hospital discharge. (Level of Evidence: C)

Class IIa

1. Preoperative use of beta blockers in patients without contraindications, particularly in those with a left ventricular ejection fraction (LVEF) greater than 30%, can be effective in reducing the risk of in-hospital mortality (Ferguson, Coombs, & Peterson, 2002; ten Broecke et al., 2003; Weightman et al., 1999). (Level of Evidence: B)
2. Beta blockers can be effective in reducing the incidence of perioperative myocardial ischemia (Chung et al., 1988; Podesser et al., 1995; Slogoff & Keats, 1988; Wiesbauer et al., 2007). (Level of Evidence: B)
3. Intravenous administration of beta blockers in clinically stable patients unable to take oral medications is reasonable in the early postoperative period (Halonen et al., 2006). (Level of Evidence: B)

Class IIb

1. The effectiveness of preoperative beta blockers in reducing in-hospital mortality rate in patients with LVEF less than 30% is uncertain (Ferguson, Coombs, & Peterson, 2002; Lin et al., 2010). (Level of Evidence: B)

Angiotensin-converting Enzyme (ACE) Inhibitor/Angiotensin Receptor Blocker (ARB)

Class I

1. ACE inhibitors and ARBs given before CABG should be reinstated postoperatively once the patient is stable, unless contraindicated (Goyal et al., 2007; AHA et al., 2006; Oosterga et al., 2001). (Level of Evidence: B)
2. ACE inhibitors or ARBs should be initiated postoperatively and continued indefinitely in CABG patients who were not receiving them preoperatively, who are stable, and who have an LVEF less than or equal to 40%, hypertension, diabetes mellitus, or chronic kidney disease (CKD), unless contraindicated (Goyal et al., 2007; Oosterga et al., 2001; Garg & Yusuf, 1995; Yusuf et al., 2000). (Level of Evidence: A)

Class IIa

1. It is reasonable to initiate ACE inhibitors or ARBs postoperatively and to continue them indefinitely in all CABG patients who were not receiving them preoperatively and are considered to be at low risk (i.e., those with a normal LVEF in whom cardiovascular risk factors are well controlled), unless contraindicated (Goyal et al., 2007; Oosterga et al., 2001; Garg & Yusuf, 1995; Yusuf et al., 2000; Fox et al., 2007; Kjoller-Hansen, Steffensen, & Grande, 2000; Rouleau et al., 2008). (Level of Evidence: B)

Class IIb

1. The safety of the preoperative administration of ACE inhibitors or ARBs in patients on chronic therapy is uncertain (Arora et al., 2008; Benedetto et al., 2008; Levin et al., 2009; Miceli et al., 2009; Rader et al., 2010; White et al., 2007). (Level of Evidence: B)
2. The safety of initiating ACE inhibitors or ARBs before hospital discharge is not well established (Goyal et al., 2007; Fox et al., 2007; Rouleau et al., 2008; Eagle et al., 2004). (Level of Evidence: B)

Smoking Cessation

Class I

1. All smokers should receive in-hospital educational counseling and be offered smoking cessation therapy during CABG hospitalization (Hilleman, Mohiuddin, & Packard, 2004; Rigotti, Munafo, & Stead, 2008; Smith & Burgess, 2009). (Level of Evidence: A)

Class IIb

1. The effectiveness of pharmacological therapy for smoking cessation offered to patients before hospital discharge is uncertain. (Level of Evidence: C)

Emotional Dysfunction and Psychosocial Considerations

Class IIa

1. Cognitive behavior therapy or collaborative care for patients with clinical depression after CABG can be beneficial to reduce objective measures of depression (Blumenthal et al., 2003; Connerney, et al., 2001; Freedland et al., 2009; Rollman, et al., "Telephone," 2009; Rollman et al., "The Bypassing the Blues," 2009). (Level of Evidence: B)

Cardiac Rehabilitation

Class I

1. Cardiac rehabilitation is recommended for all eligible patients after CABG (Engblom et al., 1997; Hansen et al., 2009; Milani & Lavie, 1998; Taylor et al., 2004; Clark et al., 2005; Thomas et al., 2007; Walther et al., 2008). (Level of Evidence: A)

Perioperative Monitoring

Electrocardiographic Monitoring

Class I

1. Continuous monitoring of the electrocardiogram for arrhythmia should be performed for at least 48 hours in all patients after CABG (Andrews et al., 1991; Drew et al., 2004; Echahidi et al., 2008). (Level of Evidence: B)

Class IIa

1. Continuous ST-segment monitoring for detection of ischemia is reasonable in the intraoperative period for patients undergoing CABG (Slogoff & Keats, 1985; Gordon et al., 1991; Jain et al., 1997; Knight et al., 1988). (Level of Evidence: B)

Class IIb

1. Continuous ST-segment monitoring for detection of ischemia may be considered in the early postoperative period after CABG (Podesser et al., 1995; Drew et al., 2004; Mangano et al., 1992; Zvara et al., 2000; Berry et al., 1998; Cheng et al., "Morbidity," 1996). (Level of Evidence: B)

Pulmonary Artery Catheterization

Class I

1. Placement of a pulmonary artery catheter (PAC) is indicated, preferably before the induction of anesthesia or surgical incision, in patients in cardiogenic shock undergoing CABG. (Level of Evidence: C)

Class IIa

1. Placement of a PAC can be useful in the intraoperative or early postoperative period in patients with acute hemodynamic instability (American Society of Anesthesiologists Task Force on Pulmonary Artery Catheterization, 2003; Pearson et al., 1989; Resano et al., 2006; Schwann et al., 2002; Stewart et al., 1998; Tuman et al., 1989). (Level of Evidence: B)

Class IIb

1. Placement of a PAC may be reasonable in clinically stable patients undergoing CABG after consideration of baseline patient risk, the planned surgical procedure, and the practice setting (American Society of Anesthesiologists Task Force on Pulmonary Artery Catheterization, 2003; Pearson et al., 1989; Resano et al., 2006; Schwann et al., 2002; Stewart et al., 1998; Tuman et al., 1989). (Level of Evidence: B)

Central Nervous System Monitoring

Class IIb

1. The effectiveness of intraoperative monitoring of the processed electroencephalogram to reduce the possibility of adverse recall of clinical events or for detection of cerebral hypoperfusion in CABG patients is uncertain (Avidan et al., 2008; Hemmerling et al., 2005; Myles et al., 2004). (Level of Evidence: B)
2. The effectiveness of routine use of intraoperative or early postoperative monitoring of cerebral oxygen saturation via near-infrared spectroscopy to detect cerebral hypoperfusion in patients undergoing CABG is uncertain (Brady et al., 2010; Murkin et al., 2007; Slater et al., 2009). (Level of Evidence: B)

CABG-Associated Morbidity and Mortality: Occurrence and Prevention

Public Reporting of Cardiac Surgery Outcomes

Class I

1. Public reporting of cardiac surgery outcomes should use risk-adjusted results based on clinical data (Geraci et al., 2005; Hannan et al., 1992; Hannan et al., 1997; Hartz et al., 1994; Jones et al., "Identification," 1996; Mack et al., 2005; Shahian et al., 2007; Tu, Sykora, & Naylor, 1997). (Level of Evidence: B)

Use of Outcomes or Volume as CABG Quality Measures

Class I

1. All cardiac surgery programs should participate in a state, regional, or national clinical data registry and should receive periodic reports of their risk-adjusted outcomes. (Level of Evidence: C)

Class IIa

1. When credible risk-adjusted outcomes data are not available, volume can be useful as a structural metric of CABG quality (Shahian et al., 2010; Hannan et al., 1995; Clark, 1996; Grumbach et al., 1995; Hannan et al., 1991; Hannan et al., 2003; Kalant & Shrier, 2004; Nallamothu et al., 2001; Peterson et al., 2004; Rathore et al., 2004; Showstack et al., 1987; Shroyer et al., 1996; Sowden, Deeks, & Sheldon, 1995; Welke et al., 2005; Wu et al., 2004; Luft, Bunker, & Enthoven, 1979; Birkmeyer et al., 2002). (Level of Evidence: B)

Class IIb

1. Affiliation with a high-volume tertiary center might be considered by cardiac surgery programs that perform fewer than 125 CABG procedures annually. (Level of Evidence: C)

Adverse Events

Stroke

Use of Epi-aortic Ultrasound Imaging to Reduce Stroke Rates

Class IIa

1. Routine epiaortic ultrasound scanning is reasonable to evaluate the presence, location, and severity of plaque in the ascending aorta to reduce the

incidence of atheroembolic complications (Nakamura et al., 2008; Rosenberger et al., 2008; Yamaguchi et al., 2009). (Level of Evidence: B)

The Role of Preoperative Carotid Artery Noninvasive Screening in CABG Patients

Class I

1. A multidisciplinary team approach (consisting of a cardiologist, cardiac surgeon, vascular surgeon, and neurologist) is recommended for patients with clinically significant carotid artery disease for whom CABG is planned. (Level of Evidence: C)

Class IIa

1. Carotid artery duplex scanning is reasonable in selected patients who are considered to have high-risk features (i.e., age >65 years, left main coronary stenosis, peripheral artery disease [PAD], history of cerebrovascular disease [transient ischemic attack (TIA), stroke, etc.], hypertension, smoking, and diabetes mellitus) (Durand et al., 2004; Sheiman & Janne d'Orthee, 2007). (Level of Evidence: C)
2. In the CABG patient with a previous TIA or stroke and a significant (50% to 99%) carotid artery stenosis, it is reasonable to consider carotid revascularization in conjunction with CABG. In such an individual, the sequence and timing (simultaneous or staged) of carotid intervention and CABG should be determined by the patient's relative magnitudes of cerebral and myocardial dysfunction. (Level of Evidence: C)

Class IIb

1. In the patient scheduled to undergo CABG who has no history of TIA or stroke, carotid revascularization may be considered in the presence of bilateral severe (70% to 99%) carotid stenoses or a unilateral severe carotid stenosis with a contralateral occlusion. (Level of Evidence: C)

Mediastinitis/Perioperative Infection

Class I

1. Preoperative antibiotics should be administered to all patients to reduce the risk of postoperative infection (Kreter & Woods 1992; Goodman et al., 1968; Fong, Baker, & McKee, 1979; Fekety et al., 1969; Austin et al., 1980; Kaiser et al., 1987). (Level of Evidence: A)
2. A first- or second-generation cephalosporin is recommended for prophylaxis in patients without methicillin-resistant *Staphylococcus aureus* colonization (Kaiser et al., 1987; Bolon et al., 2004; Finkelstein, et al., 2002; Maki et al., 1992; Saginur, Croteau, & Bergeron, 2000; Salminen et al., 1999; Townsend et al., 1993; Vuorisalo, Pokela, & Syrjala, 1998; Wilson et al., 1988). (Level of Evidence: A)
3. Vancomycin alone or in combination with other antibiotics to achieve broader coverage is recommended for prophylaxis in patients with proven or suspected methicillin-resistant *S. aureus* colonization (Maki et al., 1992; Centers for Diseases Control and Prevention [CDC], 2010; Spelman et al., 2002; Walsh, Greene, & Kirshner, 2011). (Level of Evidence: B)
4. A deep sternal wound infection should be treated with aggressive surgical debridement in the absence of complicating circumstances. Primary or secondary closure with muscle or omental flap is recommended (Jurkiewicz et al., 1980; Rand et al., 1998; Wong et al., 2006). Vacuum therapy in conjunction with early and aggressive debridement is an effective adjunctive therapy (Argenta & Morykwas, 1997; Baillot et al., 2010; Cowan et al., 2005; Doss et al., 2002; Ennker et al., 2009; Fleck et al., 2006; Fleck et al., 2002; Luckraz et al., 2003; Sjogren et al., "Clinical," 2005; Sjogren et al., "The impact," 2005). (Level of Evidence: B)
5. Use of a continuous intravenous insulin protocol to achieve and maintain an early postoperative blood glucose concentration less than or equal to 180 mg/dL while avoiding hypoglycemia is indicated to reduce the risk of deep sternal wound infection (van den Berghe et al., 2001; Gandhi et al., 2007; Ouattara et al., 2005; Doenst et al., 2005; Furnary & Wu, 2006; Kirdemir et al., 2008). (Level of Evidence: B)

Class IIa

1. When blood transfusions are needed, leukocyte-filtered blood can be useful to reduce the rate of overall perioperative infection and in-hospital death (Bilgin et al., 2004; Blumberg et al., 2002; Romano et al., 2010; van de Watering et al., 1998). (Level of Evidence: B)
2. The use of intranasal mupirocin is reasonable in nasal carriers of *S. aureus* (Konvalinka, Errett, & Fong, 2006; van Rijen et al., 2008). (Level of Evidence: A)
3. The routine use of intranasal mupirocin is reasonable in patients who are not carriers of *S. aureus*, unless an allergy exists. (Level of Evidence: C)

Class IIb

1. The use of bilateral internal mammary arteries (IMAs) in patients with diabetes mellitus is associated with an increased risk of deep sternal wound infection, but it may be reasonable when the overall benefit to the patient outweighs this increased risk. (Level of Evidence: C)

Renal Dysfunction

Class IIb

1. In patients with preoperative renal dysfunction (creatinine clearance <60 mL/min), off-pump CABG may be reasonable to reduce the risk of acute kidney injury (AKI) (Ascione et al., 2001; Chukwuemeka et al., 2005; Di Mauro et al., 2007; Nigwekar et al., 2009; Sajja et al., 2007). (Level of Evidence: B)
2. In patients with preexisting renal dysfunction undergoing on-pump CABG, maintenance of a perioperative hematocrit greater than 19% and mean arterial

- pressure greater than 60 mm Hg may be reasonable. (Level of Evidence: C)
3. In patients with preexisting renal dysfunction, a delay of surgery after coronary angiography may be reasonable until the effect of radiographic contrast material on renal function is assessed (Del Duca et al., 2007; Medalion et al., 2010; Ranucci et al., 2008). (Level of Evidence: B)
 4. The effectiveness of pharmacological agents to provide renal protection during cardiac surgery is uncertain (Adabag et al., 2009; Amar & Fleisher, 2001; Caimmi et al., 2003; Cogliati et al., 2007; Davis & Giesecke, 2000; El-Hamamsy et al., 2007; Fansa et al., 2003; Fischer, Tossios & Mehlhorn, 2005; Friedrich et al., 2005; Haase et al., 2007; Ip-Yam et al., 1994; Landoni et al., 2007; Landoni et al., 2008; Murphy, Murray, & Shorten, 2001; Nigwekar & Hix, 2009; Piper et al., 2003; Ranucci et al., 2004; Ranucci et al., 2010; Sirivella, Gielchinsky, & Parsonnet, 2000; Tumlin et al., 2005; Vesely, 2003; Wang et al., 2011; Young, Diab & Kirsh, 1998). (Level of Evidence: B)

Perioperative Myocardial Dysfunction

Class IIa

1. In the absence of severe, symptomatic aorto-iliac occlusive disease or PAD, the insertion of an intra-aortic balloon is reasonable to reduce mortality rate in CABG patients who are considered to be at high risk (e.g., those who are undergoing reoperation or have LVEF <30% or left main CAD) (Christenson et al., 2002; Christenson et al., 1999; Christenson, Licker, & Kalangos, 2003; Christenson, Schmuziger, & Simonet, 2001; Urban et al., 2004; Santa-Cruz, Cohen, & Ohman, 2006). (Level of Evidence: B)
2. Measurement of biomarkers of myonecrosis (e.g., creatine kinase-MB, troponin) is reasonable in the first 24 hours after CABG (Yau et al., 2008). (Level of Evidence: B)

Transfusion

Class I

1. Aggressive attempts at blood conservation are indicated to limit hemodilutional anemia and the need for intraoperative and perioperative allogeneic red blood cell transfusion in CABG patients (Koch et al., 2006; Surgenor et al., 2006; van Straten et al., "Transfusion," 2010; van Straten et al., "Risk factors," 2010). (Level of Evidence: B)

Perioperative Dysrhythmias

Class I

1. Beta blockers should be administered for at least 24 hours before CABG to all patients without contraindications to reduce the incidence or clinical sequelae of postoperative AF (Crystal et al., 2004; Connolly et al., 2003; Andrews et al., 1991; Mariscalco et al., 2008; Fuster et al., 2011; Al-Khatib et al., 2009; Silverman, Wright, & Levitsky, 1982; Ali, Sanalla, & Clark, 1997). (Level of Evidence: B)
2. Beta blockers should be reinstated as soon as possible after CABG in all patients without contraindications to reduce the incidence or clinical sequelae of AF (Crystal et al., 2004; Connolly et al., 2003; Andrews et al., 1991; Mariscalco et al., 2008; Fuster et al., 2011; Al-Khatib et al., 2009; Silverman, Wright, & Levitsky, 1982; Ali, Sanalla, & Clark, 1997). (Level of Evidence: B)

Class IIa

1. Preoperative administration of amiodarone to reduce the incidence of postoperative AF is reasonable for patients at high risk for postoperative AF who have contraindications to beta blockers (Daoud et al., 1997). (Level of Evidence: B)
2. Digoxin and nondihydropyridine calcium channel blockers can be useful to control the ventricular rate in the setting of AF but are not indicated for prophylaxis (Andrews et al., 1991; Williams et al., 1985; Davison et al., 1985; Tyras et al., 1979; Weiner et al., 1986; Johnson et al., 1976). (Level of Evidence: B)

Perioperative Bleeding/Transfusion

Class I

1. Lysine analogues are useful intra-operatively and post-operatively in patients undergoing on-pump CABG to reduce perioperative blood loss and transfusion requirements (Fergusson et al., 2008; Greilich et al., 2009; Kikura et al., 2006; Mehr-Aein, Sadeghi, & Madani-civi, 2007; Mehr-Aein, Davoodi, & Madani-civi, 2007; Murphy et al., 2006; Santos et al., 2006; Taghaddomi et al., 2009). (Level of Evidence: A)
2. A multimodal approach with transfusion algorithms, point-of-care testing, and a focused blood conservation strategy should be used to limit the number of transfusions (Paone, Spencer, & Silverman, 1994; Nuttall et al., 2001; Royston & von Kier, 2001; Avidan et al., 2004; Despotis, Grishaber, & Goodnough, 1994; Shore-Lesserson et al., 1999). (Level of Evidence: A)
3. In patients taking thienopyridines (clopidogrel or prasugrel) or ticagrelor in whom elective CABG is planned, clopidogrel and ticagrelor should be withheld for at least 5 days (Berger et al., 2008; Held et al., 2011; Firanscu et al., 2009; Herman et al., 2010; Kim et al., 2008; Chu et al., 2004; Englberger et al., 2004; Kapetanakis et al., 2006; Maltais, Perrault, & Do, 2008; Vaccarino et al., 2009; Yusuf et al., 2001) (Level of Evidence: B) and prasugrel for at least 7 days (Wiviott et al., 2007) (Level of Evidence: C) before surgery.
4. It is recommended that surgery be delayed after the administration of streptokinase, urokinase, and tissue-type plasminogen activators until hemostatic capacity is restored, if possible. The timing of recommended delay should be guided by the pharmacodynamic half-life of the involved agent. (Level of Evidence: C)

5. Tirofiban or eptifibatide should be discontinued at least 2 to 4 hours before CABG and abciximab at least 12 hours before CABG (Bizzarri et al., 2001; Dyke et al., 2000; Lincoff et al., 2000; Murphy et al., 2006; Santos et al., 2006; Renda et al., 2007; McDonald et al., 2005; Jones et al., 2002; Kincaid et al., 2003; Medalion et al., 2003). (Level of Evidence: B).

Class IIa

1. It is reasonable to consider off-pump CABG to reduce perioperative bleeding and allogeneic blood transfusion (Khan et al., 2004; Angelini et al., 2002; Cheng et al., 2005; Czerny et al., 2001; Puskas et al., 2003; Raja & Dreyfuss, 2006; van Dijk et al., 2001). (Level of Evidence: A)

Specific Patient Subsets

Anomalous Coronary Arteries

Class I

1. Coronary revascularization should be performed in patients with:
 - a. A left main coronary artery that arises anomalously and then courses between the aorta and pulmonary artery (Basso et al., 2000; Thomas et al., 1991; Krasuski et al., 2011). (Level of Evidence: B)
 - b. A right coronary artery that arises anomalously and then courses between the aorta and pulmonary artery with evidence of myocardial ischemia (Basso et al., 2000; Thomas et al., 1991; Krasuski et al., 2011; Frommelt et al., 2011). (Level of Evidence: B)

Class IIb

1. Coronary revascularization may be reasonable in patients with a LAD coronary artery that arises anomalously and then courses between the aorta and pulmonary artery. (Level of Evidence: C)

Patients with Chronic Obstructive Pulmonary Disease/Respiratory Insufficiency

Class IIa

1. Preoperative intensive inspiratory muscle training is reasonable to reduce the incidence of pulmonary complications in patients at high risk for respiratory complications after CABG (Hulzebos et al., 2006). (Level of Evidence: B)

Class IIb

1. After CABG, noninvasive positive pressure ventilation may be reasonable to improve pulmonary mechanics and to reduce the need for reintubation (Haefner et al., 2008; Zarbock et al., 2009). (Level of Evidence: B)
2. High thoracic epidural analgesia may be considered to improve lung function after CABG (Liu, Block, & Wu, 2004; Koidis et al., 2008). (Level of Evidence: B)

Patients with End-Stage Renal Disease on Dialysis

Class IIb

1. CABG to improve survival rate may be reasonable in patients with end-stage renal disease undergoing CABG for left main coronary artery stenosis of greater than or equal to 50% (Hemmelgarn et al., 2004). (Level of Evidence: C)
2. CABG to improve survival rate or to relieve angina despite GDMT may be reasonable for patients with end-stage renal disease with significant stenoses ($\geq 70\%$) in 3 major vessels or in the proximal LAD artery plus 1 other major vessel, regardless of LV systolic function (Liu et al., 2000). (Level of Evidence: B)

Class III: HARM

1. CABG should not be performed in patients with end-stage renal disease whose life expectancy is limited by noncardiac issues. (Level of Evidence: C)

Patients with Concomitant Valvular Disease

Class I

1. Patients undergoing CABG who have at least moderate aortic stenosis should have concomitant aortic valve replacement (Filsoufi et al., 2002; Smith et al., 2004; Pereira et al., 2005; Gillinov & Garcia, 2005). (Level of Evidence: B)
2. Patients undergoing CABG who have severe ischemic mitral valve regurgitation not likely to resolve with revascularization should have concomitant mitral valve repair or replacement at the time of CABG (Gillinov et al., 2001; Aklog et al., 2001; Trichon et al., 2003; Fattouch et al., 2009; Fattouch et al., 2010; Zoghbi & Sarano, 2003). (Level of Evidence: B)

Class IIa

1. In patients undergoing CABG who have moderate ischemic mitral valve regurgitation not likely to resolve with revascularization, concomitant mitral valve

repair or replacement at the time of CABG is reasonable (Gillinov et al., 2001; Aklog et al., 2001; Trichon et al., 2003; Fattouch et al., 2009; Fattouch et al., 2010; Zoghbi & Sarano, 2003). (Level of Evidence: B)

Class IIb

1. Patients undergoing CABG who have mild aortic stenosis may be considered for concomitant aortic valve replacement when evidence (e.g., moderate-severe leaflet calcification) suggests that progression of the aortic stenosis may be rapid and the risk of the combined procedure is acceptable. (Level of Evidence: C)

Patients with Previous Cardiac Surgery

Class IIa

1. In patients with a patent LIMA to the LAD artery and ischemia in the distribution of the right or left circumflex coronary arteries, it is reasonable to recommend reoperative CABG to treat angina if GDMT has failed and the coronary stenoses are not amenable to PCI (Subramanian et al., 2009; Sergeant, Blackstone, & Meyns, 1998). (Level of Evidence: B)

Definitions:

Applying Classification of Recommendations and Level of Evidence

		Size of Treatment Effect					
		CLASS I <i>Benefit >>> Risk</i> Procedure/Treatment SHOULD be performed/administered	CLASS IIa <i>Benefit >> Risk</i> <i>Additional studies with focused objectives needed</i> IT IS REASONABLE to perform procedure/administer treatment	CLASS IIb <i>Benefit ≥ Risk</i> <i>Additional studies with broad objectives needed; additional registry data would be helpful</i> Procedure/Treatment MAY BE CONSIDERED	CLASS III No Benefit or Class III Harm		
Estimate of Certainty (Precision) of Treatment Effect	LEVEL A Multiple populations evaluated* Data derived from multiple randomized clinical trials or meta-analyses	<ul style="list-style-type: none"> • Recommendation that procedure or treatment is useful/effective • Sufficient evidence from multiple randomized trials or meta-analyses 	<ul style="list-style-type: none"> • Recommendation in favor of treatment or procedure being useful/effective • Some conflicting evidence from multiple randomized trials or meta-analyses 	<ul style="list-style-type: none"> • Recommendation's usefulness/efficacy less well established • Greater conflicting evidence from multiple randomized trials or meta-analyses 	COR III: No benefit	Procedure/Test	Treatment
					COR III: Harm	Excess Cost without Benefit or Harmful	Harmful to Patients
	LEVEL B Limited populations evaluated* Data derived from a single randomized clinical trials or nonrandomized studies	<ul style="list-style-type: none"> • Recommendation that procedure or treatment is useful/effective • Evidence from single randomized trial or nonrandomized studies 	<ul style="list-style-type: none"> • Recommendation in favor of treatment or procedure being useful/effective • Some conflicting evidence from single randomized trial or nonrandomized studies 	<ul style="list-style-type: none"> • Recommendation's usefulness/efficacy less well established • Greater conflicting evidence from single randomized trial or nonrandomized studies 	<ul style="list-style-type: none"> • Recommendation that procedure or treatment is not useful/effective and may be harmful • Sufficient evidence from multiple randomized trials or meta-analyses 		
					<ul style="list-style-type: none"> • Recommendation that procedure or treatment is not useful/effective and may be harmful • Evidence from single randomized trial or nonrandomized studies 		

	LEVEL C	Size of Treatment Effect • Recommendation that procedure or treatment is useful/effective	• Recommendation in favor of treatment or procedure being useful/effective	• Recommendation's usefulness/efficacy less well established	• Recommendation that procedure or treatment is not useful/effective and may be harmful
	<p>Very limited populations evaluated*</p> <p>Only consensus opinion of experts, case studies or standard of care</p>	<ul style="list-style-type: none"> Only expert opinion, case studies, or standard of care 	<ul style="list-style-type: none"> Only diverging expert opinion, case studies, or standard of care 	<ul style="list-style-type: none"> Only diverging expert opinion, case studies, or standard of care 	<ul style="list-style-type: none"> Only expert opinion, case studies, or standard of care

A recommendation with Level of Evidence B or C does not imply that the recommendation is weak. Many important clinical questions addressed in the guidelines do not lend themselves to clinical trials. Although randomized trials are unavailable, there may be a very clear clinical consensus that a particular test or therapy is useful or effective.

*Data available from clinical trials or registries about the usefulness/efficacy in different subpopulations, such as gender, age, history of diabetes, history of prior myocardial infarction, history of heart failure, and prior aspirin use. A recommendation with Level of Evidence B or C does not imply that the recommendation is weak. Many important clinical questions addressed in the guidelines do not lend themselves to clinical trials. Even though randomized trials are not available, there may be a very clear clinical consensus that a particular test or therapy is useful or effective.

Clinical Algorithm(s)

None provided

Scope

Disease/Condition(s)

Coronary artery diseases (CAD) including asymptomatic or mild angina, stable angina, unstable angina/non-ST-segment elevation myocardial infarction (MI), ST-segment elevation myocardial infarction (STEMI), poor left ventricular (LV) function, and life-threatening ventricular arrhythmias

Guideline Category

Management

Prevention

Screening

Treatment

Clinical Specialty

Cardiology

Family Practice

Internal Medicine

Preventive Medicine

Intended Users

Guideline Objective(s)

- To assist physicians in clinical decision making by presenting recommendations regarding the appropriate use of coronary artery bypass graft (CABG) surgery
- To assist healthcare providers in clinical decision making by describing a range of generally acceptable approaches to the diagnosis, management, and prevention of specific diseases or conditions
- To define practices that meet the needs of most patients in most circumstances

Target Population

Adults with coronary artery disease

Interventions and Practices Considered

1. Coronary artery bypass graft (CABG)
 - Intraoperative management
 - Anesthetic technique
 - Analgesia
 - Bypass graft conduit
 - Intraoperative transesophageal echocardiography (TEE)
 - Management of myocardial ischemia
 - Management of specific patient subsets
2. Coronary artery disease (CAD) revascularization
 - Heart team approach to revascularization decisions
 - Revascularization to improve survival (left main CAD revascularization, non-left main CAD revascularization)
 - Revascularization to improve symptoms
 - Percutaneous coronary intervention
 - Hybrid coronary revascularization
3. Perioperative management
 - Antiplatelet therapy
 - Management of hyperlipidemia
 - Hormonal control: blood glucose control, hormone therapy, management of hypothyroidism
 - Perioperative beta blockers
 - Angiotensin receptor blockers (ARBs), angiotensin converting enzyme (ACE) inhibitors
 - Smoking cessation
 - Management of emotional dysfunction and psychosocial considerations (cognitive behavioral therapy)
 - Cardiac rehabilitation
 - Perioperative monitoring (electrocardiogram, pulmonary artery catheterization)
4. Prevention and management of adverse events
 - Routine epiaortic ultrasound scanning
 - Multidisciplinary team approach (consisting of a cardiologist, cardiac surgeon, vascular surgeon, and neurologist)
 - Carotid artery duplex scanning
 - Carotid revascularization in conjunction with CABG
 - Mediastinitis/perioperative infection control measures
 - Preoperative antibiotics, continuous insulin, surgical debridement of deep sternal wound infection
 - Management of patients with preoperative renal dysfunction
 - Management of perioperative myocardial dysfunction (intraaortic balloon, measurement of biomarkers)
 - Aggressive blood conservation
 - Management of perioperative dysrhythmias
 - Perioperative bleeding control and transfusion
5. Management of specific patient populations

Major Outcomes Considered

- Relief of symptoms of angina
- Morbidity and mortality including:
 - Long-term survival after bypass surgery (total mortality at 5 and 10 years)
 - Hospital mortality
 - Adverse cerebral outcomes
 - Mediastinitis
 - Renal dysfunction
- Predictive value of tests
- Quality of life
- Length of hospitalization
- Incidence of myocardial infarction (MI) including ST segment elevation
- Incidence of perioperative stroke
- Incidence of neurological injury
- Incidence of perioperative myocardial dysfunction
- Repeat revascularization rates

Methodology

Methods Used to Collect/Select the Evidence

Hand-searches of Published Literature (Primary Sources)

Hand-searches of Published Literature (Secondary Sources)

Searches of Electronic Databases

Description of Methods Used to Collect/Select the Evidence

Articles reviewed in this guideline revision covered evidence from the past 10 years through January 2011, as well as selected other references through April 2011. Searches were limited to studies, reviews, and other evidence conducted in human subjects that were published in English. Key search words included but were not limited to the following: analgesia, anastomotic techniques, antiplatelet agents, automated proximal clampless anastomosis device, asymptomatic ischemia, Cardica C-port, cost effectiveness, depressed left ventricular (LV) function, distal anastomotic techniques, direct proximal anastomosis on aorta, distal anastomotic devices, emergency coronary artery bypass graft (CABG) and ST-elevation myocardial infarction (STEMI), heart failure, interrupted sutures, LV systolic dysfunction, magnetic connectors, PAS-Port automated proximal clampless anastomotic device, patency, proximal connectors, renal disease, sequential anastomosis, sternotomy, symmetry connector, symptomatic ischemia, proximal connectors, sequential anastomosis, T grafts, thoracotomy, U-clips, Ventrica Magnetic Vascular Port system, Y grafts. Additionally, the committee reviewed documents related to the subject matter previously published by the American College of Cardiology Foundation (ACCF) and the American Heart Association (AHA). References selected and published in this document are representative but not all-inclusive.

Number of Source Documents

Not stated

Methods Used to Assess the Quality and Strength of the Evidence

Weighting According to a Rating Scheme (Scheme Given)

Rating Scheme for the Strength of the Evidence

Applying Classification of Recommendations and Level of Evidence

	Size of Treatment Effect			
	CLASS I	CLASS IIa	CLASS IIb	CLASS III <i>No Benefit or Class III Harm</i>

		<i>Benefit >> Risk</i> Effect Size	<i>Benefit >> Risk</i> Additional studies	<i>Benefit ≥ Risk</i> Additional studies with		Procedure/Test	Treatment
	Procedure/Treatment SHOULD be performed/administered		<i>with focused objectives needed</i> IT IS REASONABLE to perform procedure/administer treatment	<i>broad objectives needed; additional registry data would be helpful</i> Procedure/Treatment MAY BE CONSIDERED	COR III: No benefit	Not helpful	No proven benefit
					COR III: Harm	Excess Cost without Benefit or Harmful	Harmful to Patients
Estimate of Certainty (Precision) of Treatment Effect	LEVEL A Multiple populations evaluated*	<ul style="list-style-type: none"> • Recommendation that procedure or treatment is useful/effective • Sufficient evidence from multiple randomized trials or meta-analyses 	<ul style="list-style-type: none"> • Recommendation in favor of treatment or procedure being useful/effective • Some conflicting evidence from multiple randomized trials or meta-analyses 	<ul style="list-style-type: none"> • Recommendation's usefulness/efficacy less well established • Greater conflicting evidence from multiple randomized trials or meta-analyses 	<ul style="list-style-type: none"> • Recommendation that procedure or treatment is not useful/effective and may be harmful • Sufficient evidence from multiple randomized trials or meta- analyses 		
	LEVEL B Limited populations evaluated*	<ul style="list-style-type: none"> • Recommendation that procedure or treatment is useful/effective • Evidence from single randomized trial or nonrandomized studies 	<ul style="list-style-type: none"> • Recommendation in favor of treatment or procedure being useful/effective • Some conflicting evidence from single randomized trial or nonrandomized studies 	<ul style="list-style-type: none"> • Recommendation's usefulness/efficacy less well established • Greater conflicting evidence from single randomized trial or nonrandomized studies 	<ul style="list-style-type: none"> • Recommendation that procedure or treatment is not useful/effective and may be harmful • Evidence from single randomized trial or nonrandomized studies 		
	LEVEL C Very limited populations evaluated*	<ul style="list-style-type: none"> • Recommendation that procedure or treatment is useful/effective • Only expert opinion, case studies, or standard of care 	<ul style="list-style-type: none"> • Recommendation in favor of treatment or procedure being useful/effective • Only diverging expert opinion, case studies, or standard of care 	<ul style="list-style-type: none"> • Recommendation's usefulness/efficacy less well established • Only diverging expert opinion, case studies, or standard of care 	<ul style="list-style-type: none"> • Recommendation that procedure or treatment is not useful/effective and may be harmful • Only expert opinion, case studies, or standard of care 		
	Only consensus opinion of experts, case studies or standard of care						

A recommendation with Level of Evidence B or C does not imply that the recommendation is weak. Many important clinical questions addressed in the guidelines do not lend themselves to clinical trials. Although randomized trials are unavailable, there may be a very clear clinical consensus that a particular test or therapy is useful or effective.

*Data available from clinical trials or registries about the usefulness/efficacy in different subpopulations, such as gender, age, history of diabetes, history of prior myocardial infarction, history of heart failure, and prior aspirin use. A recommendation with Level of Evidence B or C does not imply that the recommendation is weak. Many important clinical questions addressed in the guidelines do not lend themselves to clinical trials. Even though randomized trials are not available, there may be a very clear clinical consensus that a particular test or therapy is useful or effective.

Methods Used to Analyze the Evidence

Review of Published Meta-Analyses

Systematic Review with Evidence Tables

Description of the Methods Used to Analyze the Evidence

To provide clinicians with a comprehensive set of data, whenever deemed appropriate or when published, the absolute risk difference and number needed to treat or harm are provided in the guideline, along with confidence interval (CI) and data related to the relative treatment effects such as odds ratio (OR), relative risk (RR), hazard ratio (HR), or incidence rate ratio.

Methods Used to Formulate the Recommendations

Expert Consensus

Description of Methods Used to Formulate the Recommendations

Experts in the subject under consideration are selected by the American College of Cardiology Foundation (ACCF) and the American Heart Association (AHA) to examine subject-specific data and write guidelines in partnership with representatives from other medical organizations and specialty groups. Writing committees are asked to perform a formal literature review, weigh the strength of evidence for or against particular tests, treatments, or procedures; and include estimates of expected outcomes where such data exist. Patient-specific modifiers, comorbidities, and issues of patient preference that may influence the choice of tests or therapies are considered. When available, information from studies on cost is considered, but data on efficacy and outcomes constitute the primary basis for the recommendations contained herein.

In analyzing the data and developing recommendations and supporting text, the writing committee uses evidence-based methodologies developed by the Task Force. The Class of Recommendation (COR) is an estimate of the size of the treatment effect considering risks versus benefits in addition to evidence and/or agreement that a given treatment or procedure is or is not useful/effective or in some situations may cause harm. The Level of Evidence (LOE) is an estimate of the certainty or precision of the treatment effect. The writing committee reviews and ranks evidence supporting each recommendation with the weight of evidence ranked as LOE A, B, or C according to specific definitions (see the "Rating Scheme for the Strength of the Evidence" field). Studies are identified as observational, retrospective, prospective, or randomized where appropriate. For certain conditions for which inadequate data are available, recommendations are based on expert consensus and clinical experience and are ranked as LOE C. When recommendations at LOE C are supported by historical clinical data, appropriate references (including clinical reviews) are cited if available. For issues for which sparse data are available, a survey of current practice among the clinicians on the writing committee is the basis for LOE C recommendations, and no references are cited. The schema for COR and LOE is summarized in Table 1 (see the "Rating Scheme for the Strength of the Evidence" field), which also provides suggested phrases for writing recommendations within each COR. A new addition to this methodology is separation of the Class III recommendations to delineate if the recommendation is determined to be of "no benefit" or is associated with "harm" to the patient. In addition, in view of the increasing number of comparative effectiveness studies, comparator verbs and suggested phrases for writing recommendations for the comparative effectiveness of one treatment or strategy versus another have been added for COR I and IIa, LOE A or B only.

Rating Scheme for the Strength of the Recommendations

See the "Rating Scheme for the Strength of the Evidence" field, above.

Cost Analysis

Cost-Effectiveness of Coronary Artery Bypass Graft (CABG) and Percutaneous Coronary Intervention (PCI)

In the United States, it is estimated that the annual hospital costs of CABG are approximately \$10 billion. Despite the increasing risk profile of CABG candidates, it nonetheless is becoming more cost-effective. Hospital charges from the Nationwide Inpatient Sample of nearly 5.5 million patients who had isolated CABG in the United States from 1988 to 2005 were examined. A decrease in risk-adjusted mortality rate, from 6.2% to 2.1% ($p<0.0001$), was noted. When hospital costs were corrected for inflation, they declined from \$26,210 in 1988 to \$19,196 in 2005 (\$1,988) ($p<0.0001$).

Several factors tend to increase the cost of CABG, including advanced patient age, female sex, African-American ethnicity, postoperative complications, longer hospital stay, and multiple comorbidities, particularly chronic kidney disease (CKD). The National Health Service Foundation Trust in Britain found that patients >75 years of age undergoing CABG had higher rates of postoperative complications and greater resource utilization than their younger counterparts. Similarly, the Maryland Health Services Cost Review Commission reported an increased total cost and length of hospital stay with increasing age in patients undergoing CABG. The same phenomenon was not present with PCI until the patients were >80 years old. In an examination of data from 12,016 subjects

under-going CABG in New York State in 2003, it was determined that older age, female sex, and African-American ethnicity were associated with higher costs. Clinical characteristics, such as a lower LVEF, number of diseased vessels, previous open-heart operations, and numerous comorbidities, further increased costs. Larger hospitals were associated with higher CABG discharge costs, whereas costs significantly decreased with higher CABG volumes.

Not surprisingly, perioperative complications lead to increased costs. An examination of the Medicare Provider Analysis and Review file of data from 114,223 Medicare beneficiaries who survived CABG in 2005 showed the mean cost of hospitalization associated with CABG to be \$32,201 ± \$23,059 for a mean length of stay of 9.9 ± 7.8 days. Those with complications (13.6% of patients) consumed significantly more hospital resources (incremental cost, \$15,468) and had a longer length of stay (average additional stay, 1.3 days).

Evidence for the role of off-pump versus on-pump CABG in decreasing costs is conflicting. In a randomized study comparing off-pump and on-pump CABG, the mean total hospitalization cost per patient was \$2,272 less for off-pump CABG at hospital discharge and \$1,955 less at 1 year. Another study of 6,665 patients who underwent CABG between 1999 and 2005 determined that off-pump CABG provided a small short-term gain, although off-pump patients had increased long-term risks of repeat revascularization and major vascular events, especially if they were considered to be high risk. In the long run, in fact, off-pump patients utilized more resources.

Cost-Effectiveness of CABG Versus PCI

Medical costs and quality of life were examined 10 to 12 years after patients were randomly assigned to receive angioplasty or CABG in the BARI trial. Although CABG costs initially were 53% higher, the gap closed to < 5% by the end of 2 years. After 12 years, the average cost was \$123,000 in CABG patients and \$120,000 for PCI patients. Cumulative costs were significantly higher among patients with diabetes mellitus, heart failure, and comorbid conditions, and they were higher in women. CABG was deemed to be as cost-effective as PCI in patients with multivessel CAD.

The cost of coronary artery revascularization in 6,218 patients with and without CKD whose data were available in the Duke database was examined. CABG was an economically attractive alternative to PCI or medical therapy for all patients with left main or 3-vessel coronary artery disease (CAD) without concomitant CKD as well as those with 2-vessel CAD with concomitant CKD. For subjects with 3-vessel CAD and concomitant CKD, 2-vessel CAD without CKD, and 1-vessel CAD regardless of renal function, medical therapy was an economically attractive strategy compared with CABG or PCI. This analysis concluded that CABG is most economically attractive compared with PCI and medical therapy inpatients to whom it confers the greatest survival advantage and for whom the cost of alternative treatments is greatest (i.e., those with the most severe CAD). Although CABG was more expensive than medical therapy for all patients, the survival benefits associated with it were of such magnitude in some subjects that it was economically attractive.

The cost-effectiveness of CABG and PCI in high-risk patients was analyzed in the AWESOME (Angina With Extremely Serious Operative Mortality Evaluation) study, in which costs were assessed at 3 and 5 years. After 3 years, the average total cost was \$63,896 for PCI and \$84,364 for CABG, a difference of \$20,468. After 5 years, the average total cost was \$81,790 for PCI and \$100,522 for CABG, a difference of \$18,732. The authors concluded that PCI was less costly and at least as effective for urgent revascularization in high-risk patients with medically refractory angina.

CABG Versus PCI with Drug-eluting Stents (DES)

The use of DES for PCI will require a reassessment of cost-effectiveness. Although the initial procedure is considerably more expensive than the use of balloon angioplasty or bare-metal stents (BMS), equaling the cost of CABG in many patients with multivessel CAD, the cost of reintervention for restenosis may be reduced. The cost-effectiveness will depend on the pricing of stents, utilization rates of the more expensive stents, and efficacy. In a 2010 study from Japan comparing the total costs at 2 years of CABG and DES implantation in patients with left main CAD, the total costs were significantly lower for those undergoing CABG than for those receiving a DES.

Method of Guideline Validation

External Peer Review

Internal Peer Review

Description of Method of Guideline Validation

This document was reviewed by 2 official reviewers, each nominated by both the American College of Cardiology Foundation (ACCF) and the American Heart Association (AHA), as well as 1 reviewer each from the American Association for Thoracic Surgery, Society of Cardiovascular Anesthesiologists, and Society of Thoracic Surgeons (STS), as well as members from the ACCF/AHA Task Force on Data Standards, ACCF/AHA Task Force on Performance Measures, ACCF Surgeons' Scientific Council, ACCF Interventional Scientific Council, and Southern Thoracic Surgical Association.

This document was approved for publication by the governing bodies of the ACCF and the AHA and endorsed by the American Association for Thoracic Surgery, Society of Cardiovascular Anesthesiologists, and STS.

Evidence Supporting the Recommendations

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Type of Evidence Supporting the Recommendations

The type of supporting evidence is identified and graded for each recommendation (see the "Major Recommendations" field). Whenever possible, the recommendations listed in this document are evidence based.

Benefits/Harms of Implementing the Guideline Recommendations

Potential Benefits

- Increased familiarity with new evidence on coronary artery bypass graft (CABG) surgery
- Improved clinical decision making regarding appropriate use of CABG surgery
- Improved short- and long-term patient outcomes and satisfaction
- When properly applied, expert analysis of available data on the benefits and risks of these therapies and procedures can improve the quality of care, optimize patient outcomes, and favorably affect costs by focusing resources on the most effective strategies.

Potential Harms

- Attention should be directed at preventing or minimizing adverse hemodynamic and hormonal alterations that may induce myocardial ischemia or exert a deleterious effect on myocardial metabolism (as may occur during cardiopulmonary bypass [CPB])
- The safety of nonsteroidal anti-inflammatory agents for analgesia is controversial, with greater evidence for adverse cardiovascular events with the selective cyclooxygenase-2 inhibitors than the nonselective agents.
- Several adverse outcomes have been attributed to CPB, including 1) neurological deficits (e.g., stroke, coma, post-operative neurocognitive dysfunction); 2) renal dysfunction; and 3) the systemic inflammatory response syndrome (SIRS).
- Perioperative myocardial injury is associated with adverse outcomes after coronary artery bypass graft (CABG), and available data suggest a direct correlation between the amount of myonecrosis and the likelihood of an adverse outcome.
- Intraoperative hypotension is considered to be a risk factor for adverse outcomes in patients undergoing many types of surgery. Unique to CABG are unavoidable periods of hypotension associated with surgical manipulation, cannulation for CPB, weaning from CPB, or during suspension and

stabilization of the heart with off-pump CABG. Minimization of such periods is desirable but is often difficult to achieve, particularly in patients who are unstable hemodynamically.

- Potential adverse effects of perioperative statin therapy: The most common adverse effects reported with statin use are myopathy and hepatotoxicity. Muscle aches have been reported in about 5% of patients treated with statins, although several pooled analyses of randomized controlled trials (RCTs) have shown a similar rate of muscle aches with placebo. Myositis, defined as muscle pain with a serum creatine kinase >10 times the upper limit of normal, occurs in 0.1% to 0.2% of statin users, and rhabdomyolysis occurs in 0.02%. In addition, approximately 2% of patients are observed to have elevated liver enzymes (i.e., alanine and aspartate transaminases) in the weeks to months after statin initiation, but no data are available to suggest that these elevations are associated with permanent hepatotoxicity or an increased risk of hepatitis. Nonetheless, the presence of active or chronic liver disease is a contraindication to statin use, and patients initiated on a statin should be monitored for the development of myositis or rhabdomyolysis, either of which would mandate its discontinuation.
- Hormonal manipulation: Use of continuous intravenous insulin to achieve and maintain an early postoperative blood glucose concentration less than or equal to 180 mg/dL while avoiding hypoglycemia is indicated to reduce the incidence of adverse events, including deep sternal wound infection, after CABG.
- Postmenopausal hormone therapy was shown previously to reduce the risk of cardiac-related death. However, more contemporary published RCTs have suggested that it may have adverse cardiovascular effects.
- Adverse cerebral outcomes—stroke: The incidence of stroke after CABG ranges from 1.4% to 3.8%, depending on the patient population and the criteria for diagnosis of stroke. Risk factors for stroke include advanced age, history of stroke, diabetes mellitus, hypertension, and female sex, with newer research emphasizing the importance of preoperative atherosclerotic disease (including radiographic evidence of previous stroke or aortic atheromatous disease). Although macroembolization and microembolization are major sources of stroke, hypoperfusion, perhaps in conjunction with embolization, is a risk factor for postoperative stroke. The mortality rate is 10-fold higher among post-CABG patients with stroke than among those without it, and lengths of stay are longer in stroke patients.
- Transfusion of homologous blood is a risk factor for adverse outcomes after cardiac surgery.

Contraindications

Contraindications

The presence of active or chronic liver disease is a contraindication to statin use.

Qualifying Statements

Qualifying Statements

- The American College of Cardiology Foundation/American Heart Association practice guidelines are intended to assist healthcare providers in clinical decision making by describing a range of generally acceptable approaches to the diagnosis, management, and prevention of specific diseases or conditions. The guidelines attempt to define practices that meet the needs of most patients in most circumstances. The ultimate judgment regarding care of a particular patient must be made by the healthcare provider and patient in light of all the circumstances presented by that patient. As a result, situations may arise for which deviations from these guidelines may be appropriate. Clinical decision making should involve consideration of the quality and availability of expertise in the area where care is provided. When these guidelines are used as the basis for regulatory or payer decisions, the goal should be improvement in quality of care.
- The Task Force recognizes that situations arise in which additional data are needed to inform patient care more effectively; these areas will be identified within each respective guideline when appropriate. Prescribed courses of treatment in accordance with these recommendations are effective only if followed. Because lack of patient understanding and adherence may adversely affect outcomes, physicians and other healthcare providers should make every effort to engage the patient's active participation in prescribed medical regimens and lifestyles. In addition, patients should be informed of the risks, benefits, and alternatives to a particular treatment and be involved in shared decision making whenever feasible, particularly for class of recommendation (COR) IIa and IIb, where the benefit-to-risk ratio may be lower.

Implementation of the Guideline

Description of Implementation Strategy

An implementation strategy was not provided.

Implementation Tools

Pocket Guide/Reference Cards

Quick Reference Guides/Physician Guides

Slide Presentation

For information about availability, see the *Availability of Companion Documents* and *Patient Resources* fields below.

Institute of Medicine (IOM) National Healthcare Quality Report Categories

IOM Care Need

Getting Better

Staying Healthy

IOM Domain

Effectiveness

Patient-centeredness

Identifying Information and Availability

Bibliographic Source(s)

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Adaptation

Not applicable: The guideline was not adapted from another source.

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Financial Disclosures/Conflicts of Interest

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See Appendices 1 and 2 in the original guideline document for complete lists author and reviewer relationships with industry.

Guideline Endorser(s)

American Association of Thoracic Surgery - Medical Specialty Society

Society of Thoracic Surgeons - Medical Specialty Society

Guideline Status

This is the current release of the guideline.

This guideline updates a previous version: Eagle KA, Guyton RA, Davidoff R, Edwards FH, Ewy GA, Gardner TJ, Hart JC, Herrmann HC, Hillis LD, Hutter AM Jr, Lytle BW, Marlow RA, Nugent WC, Orszulak TA. ACC/AHA 2004 guideline update for coronary artery bypass graft surgery: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. Bethesda (MD): American College of Cardiology; 2004. 99 p.

Guideline Availability

Electronic copies: Available from the [American College of Cardiology Web site](#) [redacted] and the [Circulation Web site](#) [redacted].

Print copies: Available from the ACC, 2400 N Street NW, Washington DC, 20037; (800) 253-4636 (US only).

Availability of Companion Documents

The following are available:

- Hillis LD, Smith PK, et al. 2011 ACCF/AHA guideline for coronary artery bypass graft surgery: executive summary. Bethesda (MD): American College

of Cardiology/American Heart Association. 2011. 33 p. Electronic copies: Available in Portable Document Format (PDF) from the [Journal of the American College of Cardiology \(JACC\) Web site](#).

- ACCF/AHA pocket guideline. Management of patients undergoing coronary artery revascularization. Bethesda (MD): American College of Cardiology/American Heart Association. 2011 Nov. 37 p. Electronic copies: Available in PDF from the [JACC Web site](#).
- 2011 ACCF/AHA guidelines for coronary artery bypass graft surgery. Slide set. Bethesda (MD): American College of Cardiology/American Heart Association. 2011 Nov. 142 p. Electronic copies: Available from the [JACC Web site](#).
- Methodology manual and policies from the ACCF/AHA Task Force on Practice Guidelines. 2010 Jun. 88 p. American College of Cardiology Foundation and American Heart Association, Inc. Electronic copies: Available in PDF from the [American College of Cardiology \(ACC\) Web site](#).

Print copies: Available from the ACC, 2400 N Street NW, Washington DC, 20037; (800) 253-4636 (US only).

Patient Resources

None available

NGC Status

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